ANALYSIS OF RADIATION DAMAGED NANOCRYSTALLINE ALLOYS

Jozef Sitek[1], Márius Pavlovič[1], Katarína Sedlačková[1], Július Dekan[1] and Andrea Šagátová[1]

[1] Institute of Nuclear and Physical Engineering, Faculty of Electrical Engineering and Information Technology, Slovak University of Technology in Bratislava, Ilkovičova 3, 81219 Bratislava, Slovakia

E-mail: jozef.sitek@stuba.sk

Received 16 April 2015; accepted 05 May 2015

1. Introduction

In the recent years, nanocrystalline alloys have become attractive for many applications. The most prominent FINEMET, NANOPERM and HITPERM-type alloys have been frequently investigated because they exhibit excellent soft magnetic properties.

It has been already shown [1] that some physical properties of the nanocrystalline materials can be more or less affected by neutron irradiation. Changes in the orientation of the average magnetic moment were observed in neutron irradiated metallic glasses and nanocrystals [2]. The particle bombardment produces defects that may cause a realignment of magnetic domains implying a reorientation of the magnetic moments. Changes in the local neighbourhoods of the atoms affect the average hyperfine magnetic field as well as the shape of the hyperfine field distributions.

In the case of nanocrystalline alloys, which consist of crystalline nanograins embedded in an amorphous intergranular matrix irradiation by neutrons will lead to redistribution of atoms in the amorphous matrix, disturbance of regular atomic ordering of the crystal lattice and atom exchange between the amorphous and crystalline component. The mechanism of the radiation damage also depends on the constituent elements. Each of them possesses different cross-section to thermal and fast neutrons.

Radiation effect of different ions at different doses and energies on the structural changes of amorphous glasses was also studied [3]. Ribbons of amorphous $Fe_{74}Cu_1Nb_3Si_{16}B_6$ alloy were irradiated by 593 MeV Au ions to characterize the irradiation-induced structural changes.

Our work is focused on the following of structural and local magnetic modifications induced into selected alloys by irradiation by different electron doses. The method of Mössbauer spectroscopy was used to inspect the changes in the orientation of the net magnetic moment, in the value of the magnetic hyperfine field as well as in the volumetric fraction of the crystalline and the amorphous components of the nanocrystalline alloy after irradiation.

2. Experimental details

Ribbon-shaped specimens of the master alloy were prepared by planar flow casting method. The ribbons were about 25 μm thick and 10 mm wide. The nominal composition was $(Fe_{1-x}Ni_x)_{81}Nb_7B_{12}$ (x = 0, 0.25 ,0.5, 0.75). Annealing was carried out in vacuum at a temperature of 550 ºC for 1 hour. Electron irradiation was performed using linear accelerator with 1MGy dose of electrons with an energy of 5 MeV. Mössbauer spectra were collected in

transmission geometry by a conventional constant acceleration spectrometer with a ^{57}Co(Rh) source. All spectra were measured at room temperature and evaluated by the CONFIT program [4], which allows simultaneous treatment of crystalline components and residual amorphous phases using individual lines and distributions of hyperfine parameters.

3.Results and discussion

Mössbauer spectra of all samples were evaluated using a fitting model comprising two component groups, i.e. the first one consists of narrow lines attributed to the Fe-atoms situated in the bulk of nanocrystalline grains (depending on the composition, one or two sextets, eventually plus one doublet) and the second group describes the amorphous rest (either two magnetic distributions of hyperfine parameters – low-field and high-field distributions; or one hyperfine magnetic field distribution and one quadrupole splitting distribution). The details on Mössbauer spectra can be found in [5]. The decomposition of selected Mössbauer spectra is demonstrated in Fig. 1 for $(Fe_{1-x}Ni_x)_{81}Nb_7B_{12}$ (x = 0, 0.25 ,0.5, 0.75) nanocrystalline alloy.

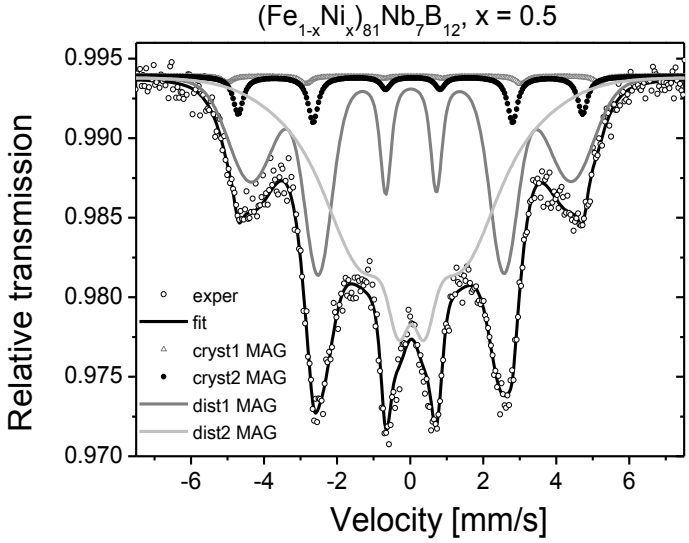

Fig.1 *Fitting model of Mössbauer spectra of the nanocrystalline alloy comprising four components*

Mössbauer spectra of the nanocrystalline samples irradiated by electrons with a dose of 1 MGy recorded at room temperature are shown in Fig. 2 .The samples were irradiated in two steps with the aim to follow the structural changes. The second irradiation was performed tree months after the first irradiation.

According to the previous measurements [5,6] after irradiation, changes in the orientation of the net magnetic moment, in the value of the average hyperfine magnetic field of the amorphous and crystalline components and of their volumetric fraction took place. Orientation of the net magnetic moment is reflect by the ratio of the second and fifth line intensities of a Mössbauer spectrum (A_{23}).This parameter achieve its maximum value if the direction of the net magnetic moment lay in sample surface and its minimum value, when is oriented perpendicular to the sample surface. Changes in the volumetric fraction of the constituent phases were found, if a part of the crystalline component was amorphised and amorphous component was also partly damaged. If the structure is only modified by irradiation, the values of the internal magnetic fields and the relative amounts of the

amorphous and crystalline components changes usually in the frame of error. In our case, A_{23} parameter is the most sensitive parameter, whose behaviour point on some changes in the direction of the net magnetic moment. A_{23} parameters of investigated samples are listed in Tab. 1.Our measurements show, that net magnetic moment turn out of the ribbon plane. After higher doses of electrons this effect is more significant.

If we compare parameters of previous neutron irradiated samples and electron irradiated samples, we can found, than the structure of the alloy is modified in both cases. Parameters of the samples irradiated by a neutron fluence of 10^{17}n/cm^2 indicated that this irradiation conditions lie near to the limit for some observable structural damage. We observed .the similar phenomena in the case of electron irradiation of the samples as is shown in Tab.1.

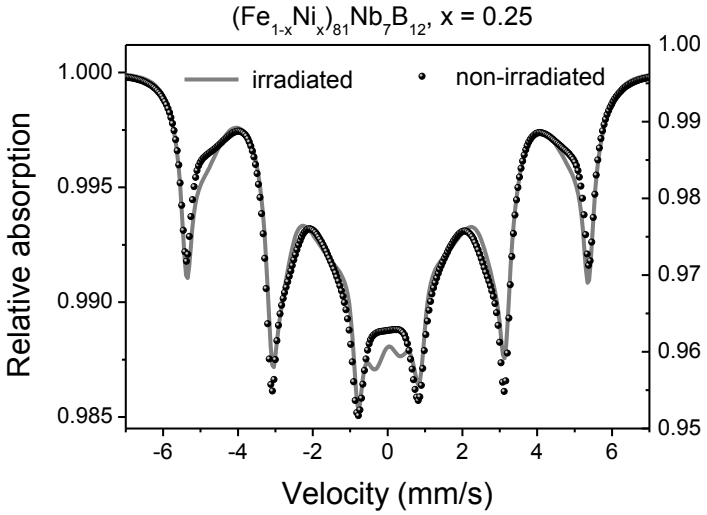

Fig. 2. *Mössbauer spectra of the $(Fe_{1-x}Ni_x)_{81}Nb_7B_{12}$ (x = 0.25) alloy after electron irradiation.*

Tab. 1. *A_{23} parameters of Mössbauer spectra*.

Fe:Ni	*electron irradiation*			*n- irrad.*
	non-irrad.	*1 MGy*	*2 MGy*	*10^{17}n/cm^2*
1:3	2.27	2.82	2.33	1.91
1:1	3.70	3.67	3.42	1.80
3:1	3.36	3.27	2.77	1.17

4.Conclusion

Nanocrystalline $Fe_{1-x}Ni_x)_{81}Nb_7B_{12}$ alloys after electron irradiation of the doses up to 2 MGy are partly modified, which is indicated from direction of net magnetic moment. New phases and changes of internal magnetic field were not observed. We suppose that for structural radiation damage higher doses of electrons are necessary.

Acknowledgement

This work was supported by the Ministry of Education, Science, Research and Sport of the Slovak Republic via the projects VEGA 1/0286/12 and APVV-0321-11

References:

[1] F.P.Shimansky, R.Gerling and R.Wagner, *Mat. Sci. Eng*. 1997**, 97**, 173
[2] J.Degmova, Ph.D.Thesis, Slovak University of Technology, Bratislava, 2001
[3] M.Miglierini, A,Lančok, M.Pavlovič, *The Physics of Metals and Metallography* 2010,**109(5),** 469–474
[4] T.Zak, Y.Jiraskova , *Surf. Interface Anal*., 2006, **38**, 710-714.
[5] J.Degmova, J.Sitek and J.M.Greneche, In: *Properties and Applications of Nanocrystalline Alloys from Amorphous Precursors*, Eds. B.Idzikowski, P.Svec, M.Miglierini, Kluwer Academic Publishers, Dodrecht,(2005)
[6] J.Sitek, J. Dekan, M. Pavlovič, *Acta Physica Polonica A* 2014, **126(1),** 84–85
[7] I.P.Hernandez, C.M.Cruz Incian, A.L.Fabelo, Y.A.Alfonso, *Nucleus*, 2007,No.41, 39-44